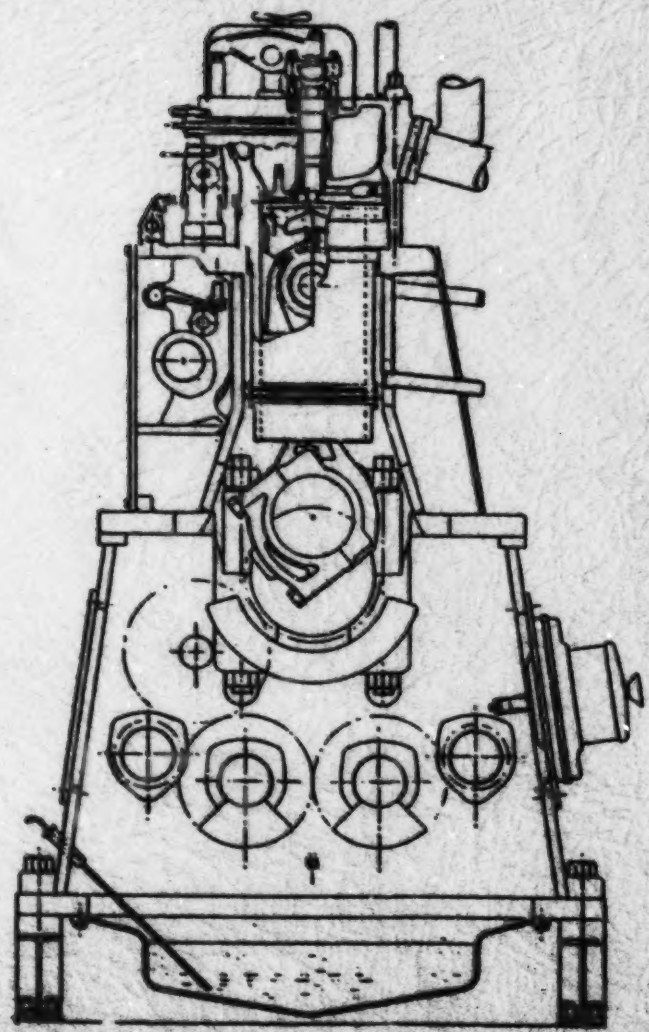
DESIGN OF A SINGLE CYLINDER MEDIUM SPEED RESEARCH ENGINE AND TEST FACILITY



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DESIGN OF A SINGLE CYLINDER MEDIUM SPEED RESEARCH ENGINE AND TEST FACILITY

BY

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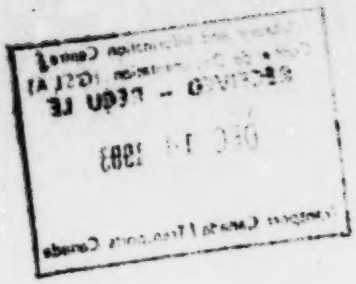
ENGINE RESEARCH AND DEVELOPMENT GROUP
RAIL AND DIESEL PRODUCTS DIVISION
BOMBARDIER INC.

AUGUST 1983



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17. Abstract

During the period of February 1982 to January 1983, the design of a single cylinder engine suitable for research into the combustion of alternate and future fuels was completed. Complementary to this task was the design of an accommodating stand-alone test facility. The adaptability of the engine allows for conversion to represent either of the two medium speed diesel engine families of Bombardier Inc.

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TEST FACILITY
ENGINE BALANCING

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17. Résumé

De février 1982 à janvier 1983, furent accomplies l'étude techniques et les plans, du moteur monocylindre pour la recherche de nouveaux combustibles ou de combustibles de remplacement. Conjointement, furent réalisés, les plans d'un banc d'essais. Cette étude permet la reconversion d'un à l'autre des deux moteurs semi-rapide Bombardier Inc.

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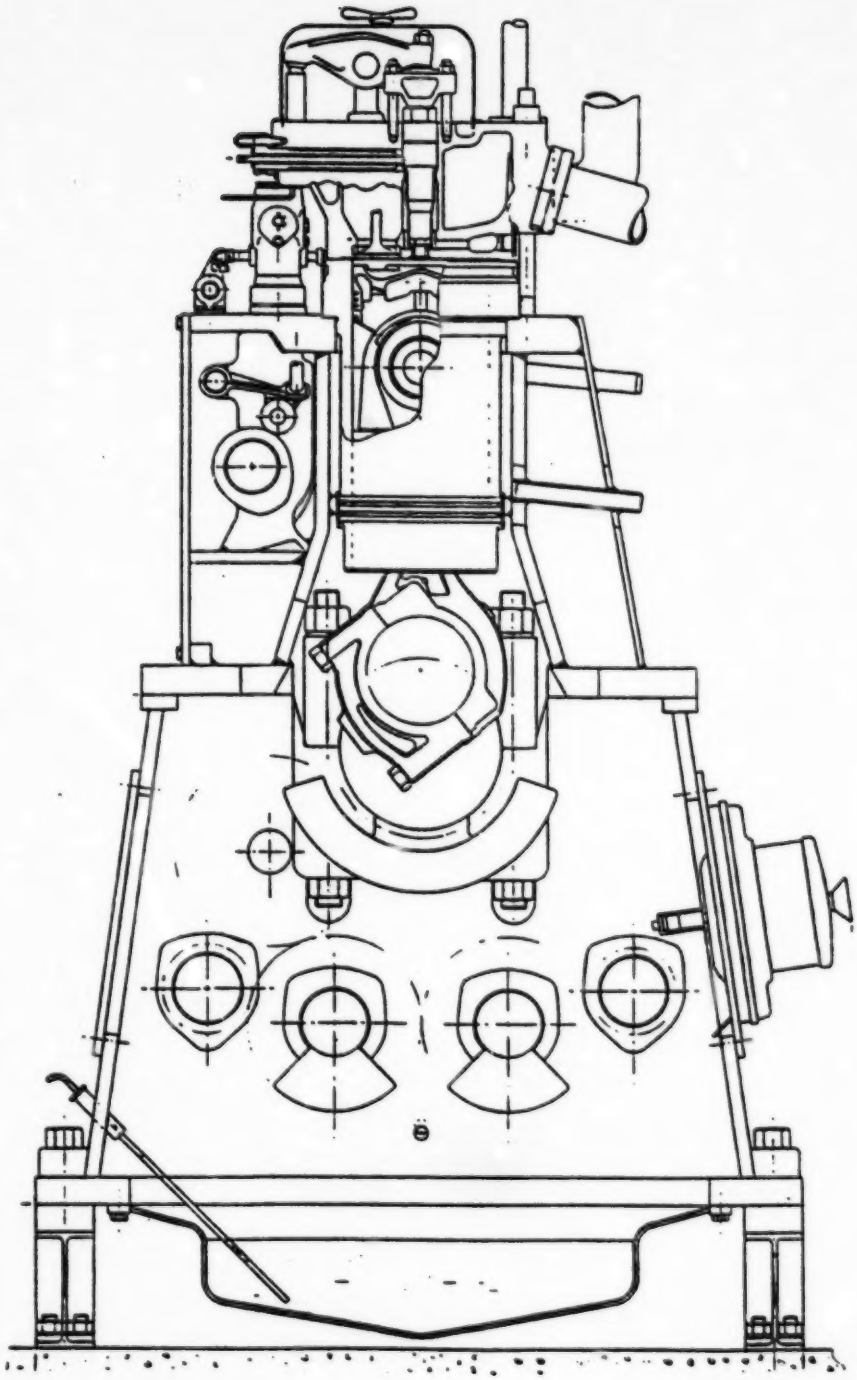

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APPENDIX "B" Functional specification, test cell

APPENDIX "C" Systems schematics

1- INTRODUCTION

Investigation into the combustion phenomena of the diesel engine using a single cylinder engine is the most cost effective means of performing such tasks, providing flexibility, maximum availability and precise studies.

This report outlines the design of the Bombardier single cylinder engine and the test facility to support it.

The philosophy of the design was based on satisfying the needs of Bombardier ie. development of the existing engine, the newly designed engine and research into off-specification and alternate fuels in medium speed engines. The spin-off of this philosophy would firstly provide a unique capability in Canada to develop technology in medium speed diesel engines.

The resulting engine design has achieved all the specified objectives, producing a research tool with a capacity beyond the current state-of-the-art.

A typical supporting stand alone facility was considered to be the best approach, for it would give the opportunity to optimize space usage and not be restricted by existing constraints i.e. equipment or buildings. The final design of the test facility is such that it could be constructed at any test establishment.

2- DESIGN PROGRAMME

This report covers the design of a medium speed single cylinder diesel engine for research and the design of the supporting test facility. As a result of a need for a research tool by Bombardier and the medium speed diesel engine industry, a contract was awarded in 1983 by Transport Canada which shared the design cost of this programme.

3- BACKGROUND (the need)

The maintenance of Bombardier in the business of producing diesel engines for locomotives stationary generator sets and marine applications requires that considerable development work be carried out in order to remain competitive in fuel economy and reliability also the need to conduct research into the combustion of future fuels (off-specification & alternative fuels) and complement a major design and development programme of a new engine series.

The use of a single cylinder engine in research is due to the economies in the cost of performing test, precise investigations (minimum of components to be adjusted and calibrated) together with adaptability.

4- PHILOSOPHY TO THE DESIGN

Five fundamental requirements formed the philosophy which the design had to follow.

1- The engine had to be representative of the Bombardier engines. The current Alco 251 series of which there are approximately three thousand in service and the

newly designed B2400 are both turbocharged.

2- A research tool, that is, it would be capable of operating outside the current and near future production, higher firing pressure together with higher and/or lower RPM.

3- Flexibility, a requirement which must be satisfied if various research studies are to be performed without major modifications to the engine, combustion studies and lube oil studies for example.

4- Components must be accessible without the need to remove unrelated items, also the ease of instrumentation had to be considered.

5- Maximum use of off-the-shelf components including engine family standard parts and maintenance hardware.

5- DESIGN CRITERIA AND SPECIFICATIONS

5.1 These were finally established after a literature review of single cylinder research engines and consultation with Ricardo Consulting Engineers who design, build and supply single cylinder engines for research, also including the Atlas single cylinder engine which is a medium speed unit uniquely designed for high BMEP studies.

The resulting design incorporated a common bed plate bottom end assembly, a 251 upper end assembly and a B2400 upper end assembly therefore meeting the requirements of both the Bombardier engine families.

5.2 DESIGN SPECIFICATIONS

Engine Configuration	251	B2400
Bore & stroke	229 mm x 267 mm	240 mm x 270 mm
Displacement	11.00 L	12.2 L
IMEP (max)	23.0 bar	25.0 bar
P_{max}	145.0 bar	175.0 bar
Crankshaft journal dia.	216 mm	240 mm
Crankpin dia.	152.4 mm	190 mm
RATED SPEEDS		
RPM	1200	1200
Piston speed	10.66 mm	10.80 mm
Idle	200	200
Overspeed	10%	

6- ENGINE COMPONENT DESIGN FEATURES

6.1 CONSTRUCTION

The longitudinal and transverse cross-section of the two engine versions are shown in Fig. 1 A & B, Appendix "A".

The lower part of the engine (bottom end) is of welded steel bed plate construction (Fig. D, Appendix "A") incorporating cast steel cross webs which support the crankshaft in three tri-metal bearings. Below the crankshaft are the primary and secondary balance shafts which are driven through a gear train by the crankshaft. This bottom end is common to both engine configurations except for the rotating mass of the primary balance shafts.

The cylinder block is of welded steel construction incorporating the chrome plated cast iron wet cylinder liner, camshaft drive gear train and camshaft which actuates the fuel pump and valves push rod.

The cast iron cylinder head supports the valve rocker and lever mechanism which actuates two inlet valves and two exhaust valves operated by the push rods.

The piston is of two part construction, a forged aluminium body and a cap of forged alloy steel. Cooling of the piston is accomplished by means of cocktail shaking oil supplied via the big end supply.

It should be stated that all components making up the power assemblies of both the 251 and B2400 versions are standard componments of those engine series.

Considerations behind the design of components unique to the single cylinder follows.

6.2 BOTTOM END

The bed plate type of crankshaft support deviates from the multi-cylinder versions of the two engine series which are underslung. However the advantages were considerable, of which some were, being able to use a common design for both engines, ease of inspection of, crankshaft main bearings and the balancing system.

The cast steel cross ribs which carry the three main bearings, one close to the flywheel and the other two

either side of the crankpin, were designed with the aid of the finite element analysis (F.E.A.) to optimize the geometrical shape of minimum weight and firing load distribution. Fig. II Appendix "A".

The balancing system consists of two counter-rotating primary and two counter-rotating secondary shafts to which,are bolted eccentric masses. These shafts are driven through a gear train from the crankshaft at the free-end of the engine. Two bronze alloyed thin steel backed bushings locate the shafts in the cross webs.

Axial movement is taken by a thrust bearing arrangement located behind the shaft drive gears.

A Bicera relief valve is located on one side of the structure and a large door on the other.

6.3 CRANKSHAFT & BEARINGS

An objective of the design was representation of the Bombardier engines and making use of as many components as possible which were readily available. Bearing load calculations indicated that the "251" main bearings would be capable of withstanding the higher forces of the "B2400", therefore allowing one bottom end to suit both engine configurations. Except for a change in stroke and larger crankpin diameter, the crankshafts are the same. The crankshaft is made of a high strenght alloyed steel forging which is nitrided and polished.

The main and big end shell bearings are of the high load

carrying, tri-metal type, designed to be compatible with the nitrided crankshaft.

6.4 CYLINDER BLOCK

The fabricated cylinder block incorporates the cylinder liner, adjustable camshaft and carries on the flywheel end a train of surface hardened gears to drive the camshaft. Access doors and clearance holes allow for adjustment or removal of the camshaft. Individual upper and lower liner cooling water inlets are provided. This feature will be necessary in the study of off-spec fuels. The cylinder liner is sealed at the bottom by two elastometric "O" rings and at the top by a single "O" ring. Coolant is supplied to the jacket and cylinder head by a remote pump.

6.5 LUBRICATING SYSTEM

A wet sump system is employed with oil circulation by a pump driven independently of the engine, which allows for easy conversion to a dry sump system. Four separate lubricating oil supplies are provided which are externally connected to a common manifold, which can be regulated for pressure and flow rate control.

1- Cylinder head
2- Camshaft and drive gears
3- Crankshaft bearings
4- Balance shafts

Some work was undertaken aimed essentially at examining the feasibility of four separate oil circuits which would

be required in the study of crankcase oils and additives. The oil under test would be confined to the main bearings, connecting rod bearing and piston cooling. All other elements requiring lubrication would be sealed off from the test oil. Provision for the separate oil drain lines and closure seals were not incorporated in the basic design. The necessary additional work will be addressed when the demand arises.

The common oil sump is designed with sloping sides and bottom, which will prevent retention of the oil under test and promote maximum circulation if a dry sump system is used.

6.6 COOLANT WATER SYSTEM

The pump which circulates the coolant is remotely located and independently driven. An external heat exchanger controls the temperature. The system is pressurized. Coolant enters the engine at the lower part of the block, travels up and around the outside of the cylinder liner, providing bore cooling, then passing to the cylinder head, circulating through the cooling passages around the valve seat and exiting at the top side of the exhaust port.

6.7 CAMSHAFT

Knowing that, to obtain optimum performance in both combustion and alternate fuel studies would require a variety of intake and exhaust event durations, the camshaft was designed with adjustable intake and exhaust cam lobes for timing and dwell with constant opening and closing ramps. The fuel cam lobe is adjustable in timing only and

has a design capacity of 2,000 bar in order to reliably produce the high injection pressures for high BMEP work.

Removal of block side cover gives direct access to the camshafts which after release of the locking devices can be rotated to the required position.

6.8 INSTRUMENTATION

Reliability, test repeatability and cost reduction are the main reasons for the use of the single cylinder engine as a research tool. This fact dictated that provisions be made in the design of the engine for easy installation of all necessary transducers. Signal generators and pickups for crankshaft and cam position indicator and triggering can be mounted on the free end of the engine. Removal of cover plates on the front gearcase allows the fitting of two instruments driven at engine speed and two instruments driven at twice engine speed by the balance shafts. All shafts are pre-drilled and tapped at the free-end including the crank and camshaft.

Methods of instrumenting the cylinder head (by inserting a pressure transducer at the flame face), high pressure fuel line and injector (for needle lift) have been devised but not included in the basic engine design covered by this report.

6.9 ENGINE PROTECTION AND CONTROL

An electric governor was chosen for two prime reasons. First, compatibility with computer engine management sys-

tems and secondly, fast response and sensitivity engine speed is sensed by a magnetic pickup mounted perpendicular to the crankshaft in proximity to the flywheel teeth. Steady state speed band is ± 0.2 percent, isochronous control. Close control of the engine speed is mandatory for accuracy and repeatability of test results.

Two fail-safe modes are built into the system. If d.c. power to the governor is interrupted or the speed reference signal is lost the output shaft returns to the minimum fuel position. This feature prevents sudden stopping of the engine under load avoiding engine seizure or the ruining of the test.

Overspeed protection is provided by a mechanical device fitted to one of the free-end rotating shafts. When the pre-set overspeed limit is reached (normally 10% above maximum speed) the fuel control rack lever is triggered which returns the rack to the minimum fuel position. In addition the usual complement of alarms monitor the lube oil, fuel, cooling water, intake air and exhaust systems.

7- TEST FACILITY

7.1 FUNCTIONAL SPECIFICATION

A prerequisite of this task was to first establish the requirements of the facility that would satisfy medium speed diesel engine research. The class of engine represented is turbocharged, which is not viable nor representative of the multi-cylinder engine. Therefore, it is necessary to provide a separate air supply to the engine and

a variable exhaust restrictor, simulating turbine back pressure.

The engine power output is absorbed by a suitable dynamometer matched to the torque curve of the engine.

The characteristics of all the supporting equipment were defined, maximum vibration and noise levels established. Calculations to determine heat transfer requirements, flow rates and all other parameters were performed during the functional specification activity.

7.2 MAJOR EQUIPMENT

From the specifications laid down in 7.1, equipment was selected and listed below:

- Dynamometer:

  Schenck: Model D630-LE water brake

  or

  Zoellner: Type 7N32F water brake.

- Air compressor:

  Joy: Model 7A-18

  1700 CFM @ 100 PSIG

  Ingersoll-Rand: Model 0C15

  1500 CFM @ 100 PSIG

- Cooling tower:

  Baltimore air coil: VXT-65

- Heat exchanger:

  American Standard:

  Jacket water cooler type 04036 CPK

  Lube oil cooler type 060036 BCF

- Air filter:

  Farr: Unipamic 59713

- Oil filter:

  Bombardier: C39-371127-001

- Pumps:

  Worthington: 01011 (water)

  Browne & Sharpe: (fuel oil)

- Surge tank:

  Bombardier: 0.5 m^3 (charge air)

- Expansion chamber:

  Bombardier: 250 L

- Silencer:

  McCarthy & Robinson: MRA06

  or

  "SPL": Model BSCRE

- Flexible coupling:

  Vulkan: EZ-86S-1100

7.3 PROCESS DIAGRAMS

6.3.1 COOLING WATER SYSTEM.

See dwg. Appendix "C" Fig. II

6.3.2 COMBUSTION CHARGE AIR SYSTEM.

See dwg. Appendix "C" Fig. III

6.3.3 LUBE OIL SYSTEM.

See Appendic "C" fig. IV

6.3.4 FUEL OIL SYSTEM.

See Appendix "C" Fig. V

6.3.5 ENGINE JACKET COOLING SYSTEM.

See Appendix "C" Fig. VI

6.3.6 DATA ACQUISITION SYSTEM.

See Appendix "C" Fig. VII

7.4 EQUIPMENT LAYOUT AND BUILDING

The test cell layout Appendix "C" Fig. 1 was decided upon after assessment of several alternative approaches. The key objective was to utilize available space for equipment installation while maintaining accessibility for maintenance purposes, such that a building of minimum size and therefore minimum cost would be the result.

The engine and dynamometer are rigidly mounted on a common skid which is attached to a concrete base approximately five times the engine mass. Direct access from main door facilitates installation and maintenance. The control room is acoustically treated with a large window which allows visibility of the engine and dynamometer.

The height of the test cell was governed by the allowance for removal of the piston and rod assembly, which in turn established the jib crane height.

Roof mounted are the cooling tower, exhaust silencer, engine intake air filters and room ventilating system.

FUNCTIONAL AND DESIGN SPECIFICATIONS

(BASIC)

1- APPLICATION

- Research into future fuels combustion for medium speed diesel engines.
- Engine component development and assessment.
- Lube oil research and classification.

2- DESIGN DATA

Engine configuration	251	B2400
Bore & Stroke	229mm x 267mm	240mm x 270mm
Displacement	10.25 L	12.2 L
IMEP (max)	23.0 bar	25.0 bar
P_{max}	145.0 bar	175.0 bar
Crankshaft Journal Dia.	216mm	240mm
Crankpin dia.	152.4mm	190mm

RATED SPEEDS

RPM	1200	1200
Piston speed	10.66m/s	10.80m/s
Idle	200	200
Overspeed	10% (30% without failure)	

FUEL INJECTION

Rate (No.2D)	1530 mm^3/inj.	1838 mm^3/inj.

2- FUNCTIONAL DATA

OVERSPEED TRIP DEVICE

Mechanical - with manual actuator.

3- GOVERNING

Electronic

4- LUBRICATION

Remote pump, dry sump - Optional
Oil: SAE 30, 40, multigrade
Flow rate: to suit

5- FUEL

Distillates
Canadian middle distillates

6- STARTING EQUIPMENT

Electric dynamometer (with motoring capability Optional)

or

Air start

7- COOLING SYSTEM

Jacket water pump - remote driven
Flow rate: to suit

8- BALANCING

Primary balance shaft gear
Secondary balance shaft
Crankshaft counter weights
(Unbalanced forces and couple to be minimized)

9- MANUFACTURING

Existing tooling and machines to be used where possible

Maximum use to be made of off the shelf components

10- UPPER END COMPONENTS

Cylinder head assembly

Piston/rod assembly

Fuel pump support assembly

Valve train components

Camshafts & gear train

11- BOTTOM END COMPONENTS

Crankshaft

Balance shafts & gear train

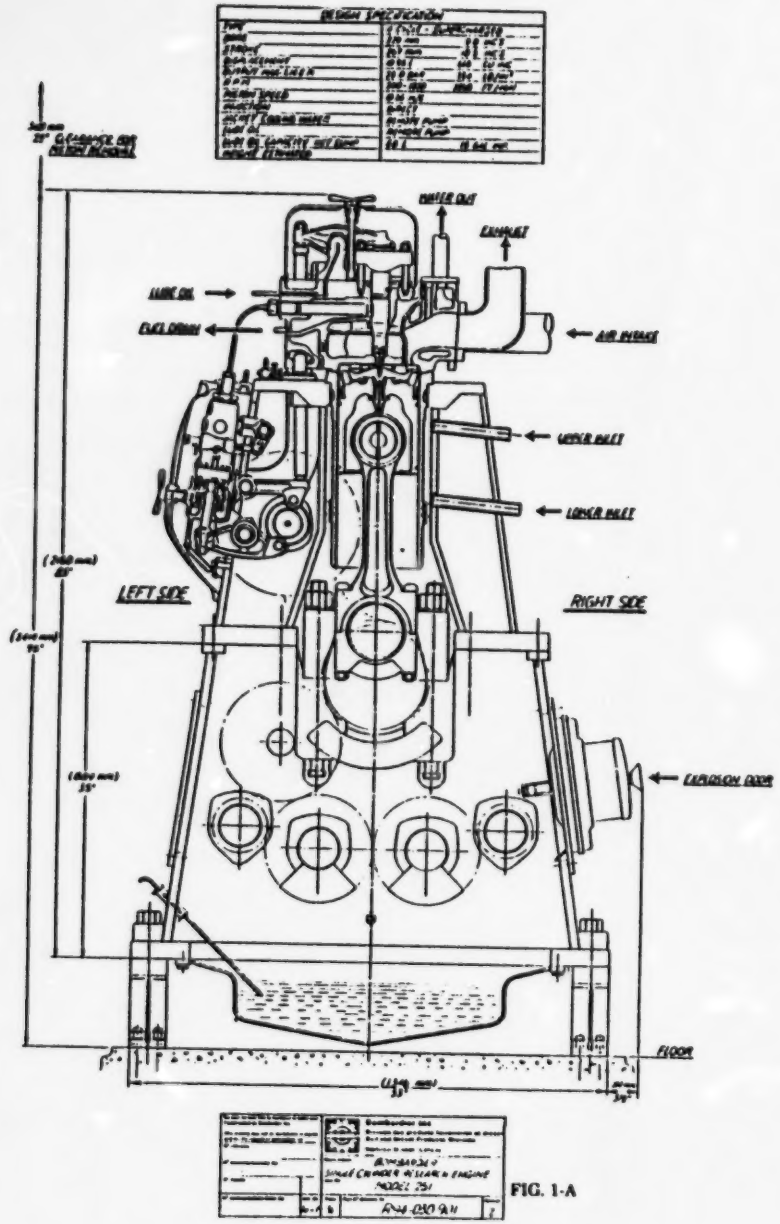


FIG. 1-A

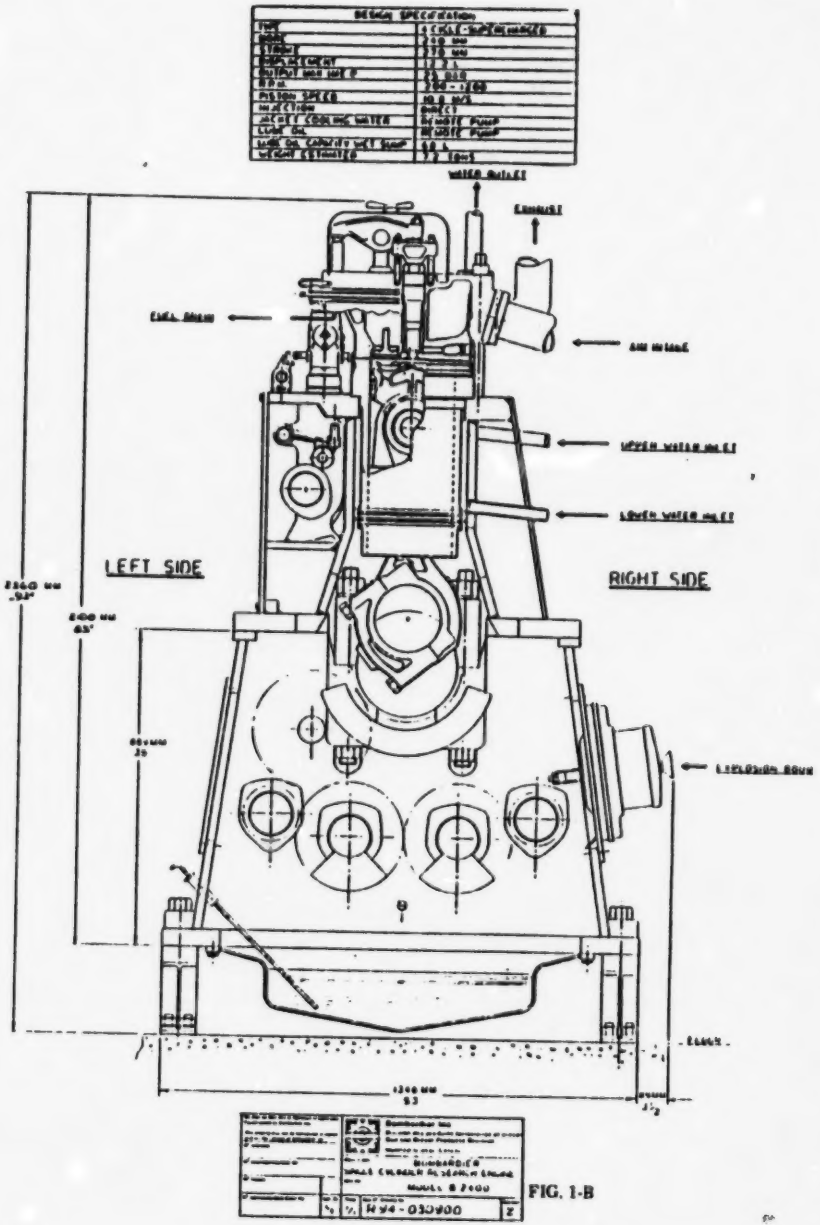
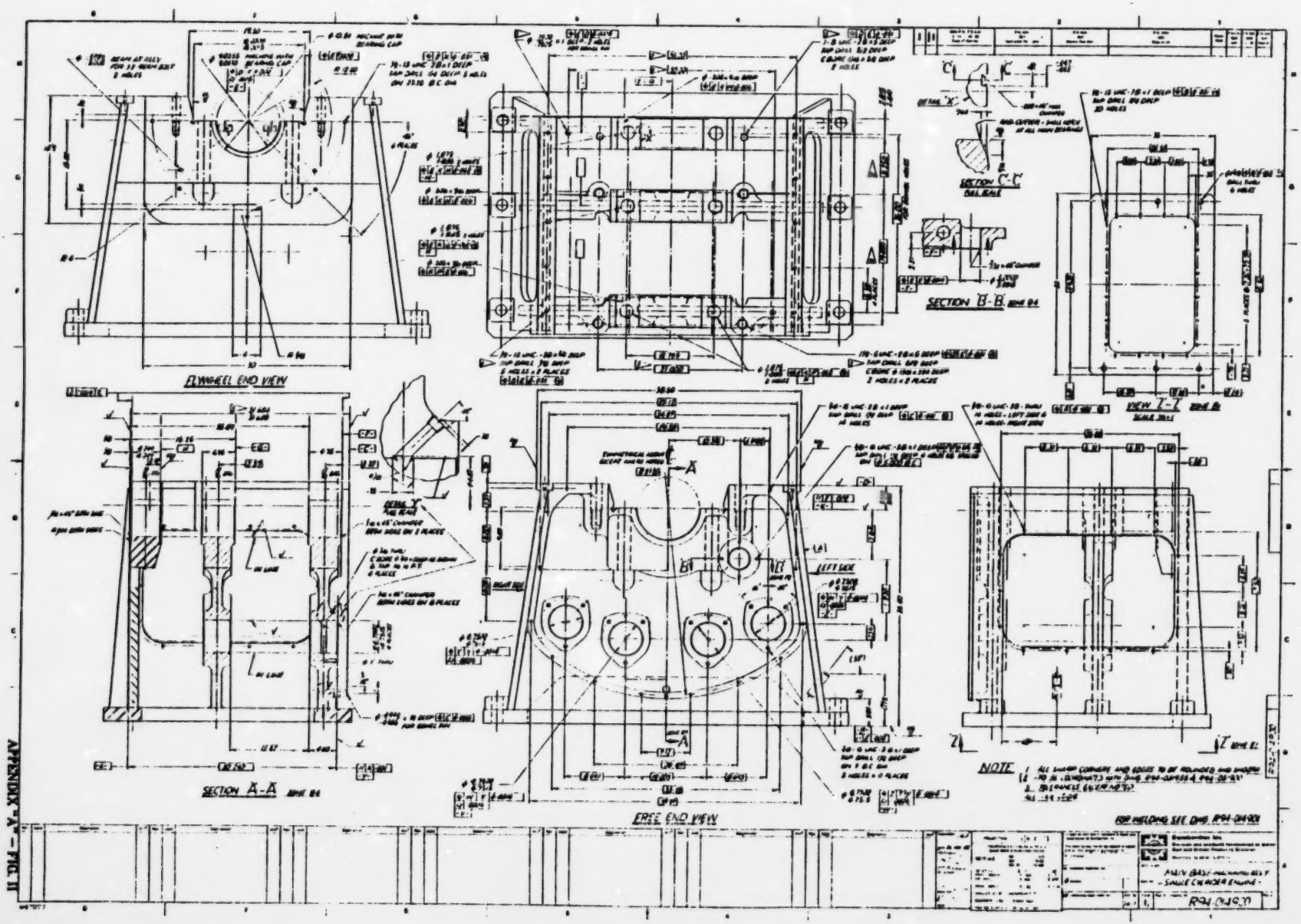
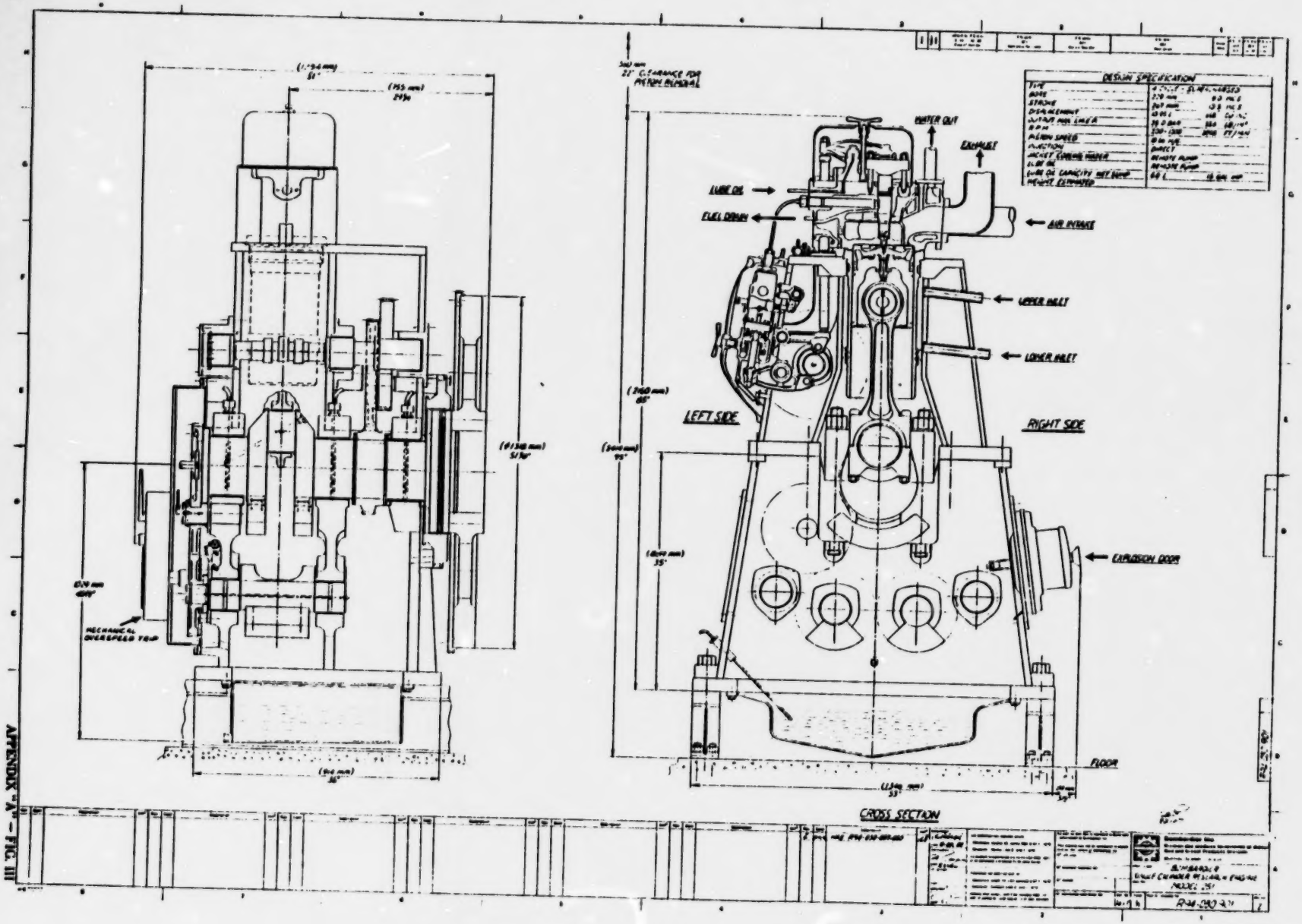


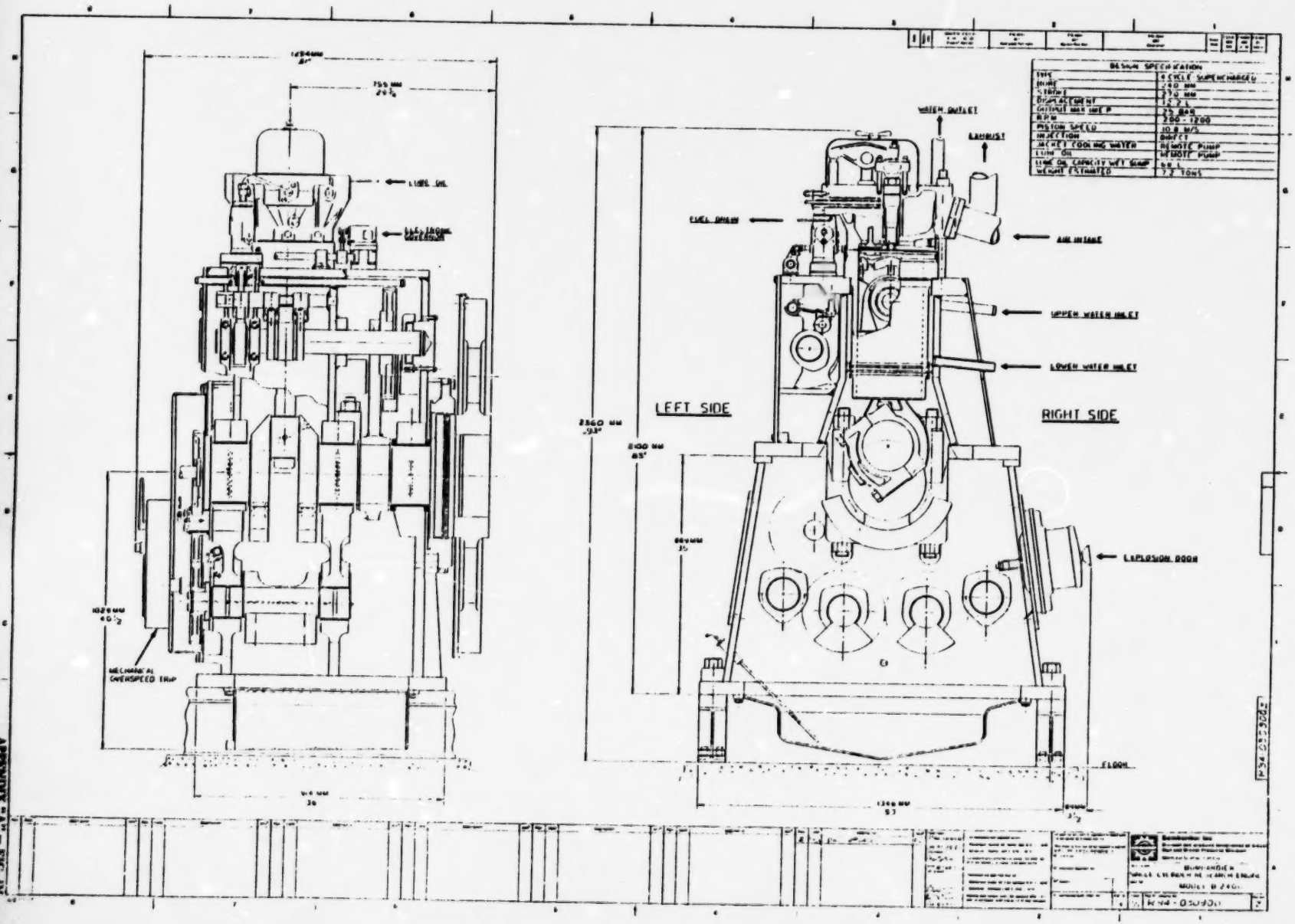
FIG. 1-B

APPENDIX "A" — FIG. 1



APPENDIX "A" - PAGE 11


DESIGN SPECIFICATION
WATER OUT
EXHAUST
LUBE OIL
FUEL DRAIN
AIR INTAKE
UPPER INLET
LOWER INLET
LEFT SIDE
RIGHT SIDE
EXPLOSION DOOR
FLOOR
CROSS SECTION


DESIGN SPECIFICATION
4 CYCLE SUPERCHARGED
LEFT SIDE
RIGHT SIDE
WATER OUTLET
EXHAUST
AIR INTAKE
UPPER WATER INLET
LOWER WATER INLET
EXPLOSION DOOR
FLOOR
MECHANICAL OVERSPEED TRIP

APPENDIX "B"

TO

REPORT 484100

DESIGN OF A SINGLE CYLINDER
MEDIUM SPEED RESEARCH ENGINE
AND TEST FACILITY

FUNCTIONAL SPECIFICATION TEST CELL

FUNCTIONAL SPECIFICATION

BOMBARDIER SINGLE CYLINDER

RESEARCH FACILITY

PROJECT NO. 484100

1- APPLICATION

Versatile test facility for research and development on:

A) Future fuels for medium speed diesel

B) Engine components

C) Lubricants

D) Combustion

2- USERS

A) Bombardier

B) Oil companies

C) Universities

D) Research centres

3- ENGINE

Single cylinder - see Functional specification

Estimated weight: 6000 kg (13200 lbs)

Nominal torque 2430 N-M (1786 lbs-Ft)

4- POWER ABSORTION SYSTEM

4-1 DYNAMOMETER

Type: - Hydraulic

- Eddy current

- Direct current

Starting and motoring capability optional
Torque: - 2430 Nm (1792 LFBT) nominal
RPM: - 1500
ROTATION: - Clockwise from flywheel end
Heat input to cooling water: - AC, 25 °C (45 °F)
Coolant flow rate: - 150 L/min (40 GPM US)
Weight: - 500 kg (1100 Lbs)

4-2 COUPLING

Torsionally flexible, deflection limit stops optional.

5- AUXILIARY SYSTEMS

5-1 COOLING WATER (cooling tower or radiator)

5-1-1 Heat input:

- Dynamoter	300 kW (402 HP)
- Engine	133 kW (178 HP)
- L.O. cooler	37 kW (50 HP)
- Charge air compressor	183 kW (245 HP)
Total input to system	653 kW (875 HP)

5-1-2 Flow rates:

- Dynamoter	150 L/min (40 GPM US)
- Engine	238 L/min (65 GPM US)
- L.O. cooler	65 L/min (17 GPM US)
- Charge air compressor	190 L/min (50 GPM US)

5-1-3 System description (cooling tower option)

5-1-3-1 Cooling tower

Capacity	653 kW (875 HP)
Temp. (wet bulb)	24 °C (75 °F)

	Temp. range	35 °C (63 °F)
	Temp. in	49 °C (120 °F)
	Temp. out	29 °C (85 °F)
	Flow rate	540 L/min (140 GPM US)
5-1-3-2	Hot well	
	Volume	1500 L (400 GAL US)
	Temp.	49 °C (120 °F)
5-1-3-3	Cold well	
	Volume	1500 L (400 GAL US)
	Temp.	29 °C (85 °F)
5-1-3-4	Heat exchanger	
	Jacket water	133 kW (178 HP)
	Lube oil	37 kW (50 HP)
	Charge air	200 kW (270 HP)
5-1-3-5	Pumps	
	- Hot water to tower:	Vane type
	Capacity	550 L/min (145 GPM US)
	Head	12 m (40 FT)
	- Cold water to tower	
	Capacity	335 L/min (89 GPM US)
	Head	15 m (50 FT)
	- Cold water to dynamometer	
	Capacity	150 L/min (40 GPM US)
	Head	15 m (50 FT)
	- Jacket water (treated)	
	Capacity	303 L/min (80 GPM US)
	Head	20 m (65 FT)
5-1-3-6	Recovery tank	
	Capacity	380 Liters(100 GPM US)
5-1-3-7	Expansion tank	
	Capacity	38 Liters(10 GAL US)
	Pressure max.	310 kPa (45 PSI)

5-1-4 System description (radiator option)

5-1-4-1 Radiator, engine

Capacity	200 kW (270 HP)
Flow rate	350 L/min (92 GPM US)

5-1-4-2 Radiator, Dynamometer

Capacity	300 kW (402 HP)
Flow rate	150 L/min (40 GPM US)

5-1-4-3 Radiator, compressor

Capacity	200 kW (270 HP)
Flow rate	190 L/min (50 GPM US)

5-1-4-4 Tanks (3 required)

Capacity	190 Liters(50 GPM US)

5-1-4-5 Pumps

- Engine

Capacity	303 L/min (80 GPM US)
Head	20 m (65 FT)

- Dynamometer

Capacity	150 L/min (40 GPM US)
Head	15 m (50 FT)

5-1-4-6 Expansion tank

Same as 5-1-3-1

5-1-5 Jacket water treatment

Boron nitrate or equal

5-2 LUBRICATING OIL SYSTEM

5-2-1 System pressure 930 kPa (135 PSI)

5-2-2 Pump

Type: Positive displacement (gear)

Capacity 250 L/min (66 GPM US)

5-2-3 Filter

Type: Paper element

Pressure Drop new	35 kPa (5 PSI)
Mean filtration rating	10 micron

5-2-4 Oil cooler

Capacity	37 kW (50 HP)
Oil flow	290 L/min (76 GPM US)
Temp. in	82 °C (180°F)
Temp. out	77 °C (171°F)

NOTE: Air to oil heat exchanger optional with radiator water cooling system.

5-2-5 Dry sump (optional)

Holding tank

Capacity	135 Liters (35 GPM US)

5-2-6 Non-stop lube oil change (optional)

Tank, flushing oil

Tank, candidate oil (used)

Tank, contaminated oil

Tank, candidate oil (new)

Tank capacity	135 Liters (35 GPM US)

5-3 FUEL OIL SYSTEM

5-3-1 Tank (12 hours)

Capacity	1000 Liters (265 GAL US)

5-3-2 Pump, booster

Type: gear

Capacity	2 L/min (0.53 GPM US)
Pressure	515 kPa (75 PSI)

5-3-3 Filter, primary (optional)

Type: Paper element

Pressure drop (new)	--- kPa (--- PSI)
Mean filtration rating	15 micron
Flow	51 L/min (15 GPM US)

5-3-4 Filter, secondary

Type: Paper element

Pressure drop(new)	--- kPa (--- PSI)
Mean filtration rating	10 micron
Flow	2 L/min (0.53GPM US)

5-3-5 Heater (later)

5-3-6 Flow meter

Range	0 - 4 liters (0 - 1GPM US) 0 - 3 kg/HR (0 - 7LB/HR)
Fluid press.	515 kPa (75 PSI)

5-3-7 Viscometer (later)

5-4 AIR INTAKE SYSTEM

5-4-1 Charge air

Flow rate	68 kg/S (1.5 lb/S)
Pressure	310 MPA (45 PSI)
Pressure ratio 4 to 1 @20 °C	(68 °F)

5-4-2 Source (Optional)

- Shop air
- Positive displacement compressor (oil less)
- Centrifugal compressor

5-4-3 Filter (not required with shop air)

Type: Paper

Particle size	5 micron 98%
Resistance	25 mmH_2O (1 in H_2O) when new
Flow	34 m^3/M (1200 CFM)
Max resistance of whole system with dirty filter	380 mmH_2O (15 in H_2O)

Oil separator (with shop air)

5-4-4 Air cooler required with compressor

Type: Intercooler and aftercooler on compressor

Total capacity	183 kW (245 JP)
Air flow	see 5-4-1
Temp air out from 50°C (125°F) to 120°C (250°F) controllable	

5-4-5 Air heater (if shor air)

Type: Electrical

Capacity	65 kW
Air flow	see 5-4-1
Temp. air in	15 °C (60°F)
Temp. air out	100 °C (212°F)

5-4-6 Surge tank

Capacity	0.5 m^3 (18 FT^3)
Pressure max	310 kPa (45 PSI)

5-5 EXHAUST SYSTEM

5-5-1 Silencer

- Max temp	700°C (1300°F) max
- Flow	105 m^3/. @ 700°C (3700 CFM @ 1300°F)
- Noise reduction	18 dBA minimum
- Back pressure	25 cm H^2O (10 in H^2O) max
- Inlet diameter	150 mm (6 in)
- Type: reactive or absorptive	
- Material: stainless steel	

5-5-2 Damper (back pressure simulation)

Diameter	150 mm (6 in)
Control:	manual or motor

5-5-3 Orifice flance

5-5-4 Expansion chamber

Size	.25 m^3 (9 FT^3)

5-6 STARTING

5-6-1	Stall torque	320 Nm (434 lbs-ft)
5-6-2	Starting speed	150 RPM
5-6-3	Mass polar moment of inertia	215 kg min^2 (1900lb. $in.sec^2$)

5-6-4 Type (optional)

5-6-4-1 Air (with hydraulic or eddy current dyno)

Pressure	1000 kPa (150 PSI) max
Flow	7 m^3 (25FT^3/start) (5 consecutive starts)

5-6-4-2 Electric (with hydraulic or eddy current dyno)

Power	3 kW (4 HP)
Voltage	... Volt
Amperage	... AMP

5-6-4-3 Dynamometer

Dynamoter with motoring capability

Power 3 kW (4 HP)

5-7 MOTORING (OPTIONAL)

RPM range 200 to 1500

Power 37 kW (50 HP)

5-7-1 Auxiliary drive

5-7-2 Direct current dynamometer

5-7-2-1 Electric energy absorption

Dissipating system

Recovery system

6- MOUNTING

6-1 Engine (options)

6-1-1 On isolated concrete base

6-1-2 On solid concrete floor

6-1-3 On solid steel base

6-1-4 On isolated steel base

6-1-5 On cushioned support stands

6-2 Dynamometer (options)

6-2-1 On isolated concrete base

6-2-2 On solid concrete

6-2-3 On solid steel base

7- BUILDING

7-1 Location

7-1-1 Existing space

7-1-2 New building

7-1-2-1 Steel structure

7-1-2-2 Concrete structure

7-2 Size

7-2-1	Engine room:	estimated	32 m^2 (345 FT^2)
			4 m x 8 m (13ft x 26ft)
		Height	4 m (13ft) clear
7-2-2	Control room:	estimated	8 m^2 (86ft^2)
			2 m x 4 m (6½ft x 13ft)

7-3 Foundation

7-3-1 Soil pressure (soil test)

7-3-2 Isolated concrete pad

7-4 Floor

7-4-1 Oil resistant finish

7-4-2 Drainage

7-4-3 Water well if required

7-5 Walls

7-5-1 Auxiliary equipment support

7-5-2 Lifting equipment support

7-5-3 Acoustic value: 45-50 STC

7-6 Roof

7-6-1 Auxiliary equipment support

7-6-1-1 Cooling tower or radiator

7-6-1-2 Silencer

7-6-1-3 Air intake filter (if req'd)

7-6-1-4 HVAC

7-6-2 Lifting equipment support

7-7- Openings

7-7-1	Main door	3.05 m x 3.65 m (10 ft x 12 ft)
	Acoustic value:	45-50 STC
7-7-2	Door	91.4 cm x 213.4 cm (3 ft x 7 ft)
	Acoustic value:	45-50 STC
7-7-3	Emergency exit control room	91.4 cm x 213.4 cm (3 ft x 7 ft)
7-7-4	Door to control room	91.4 cm x 213.4 cm (3 ft x 7 ft)
	Acoustic value	45-50 STC
7-7-5	Window acoustic	152.4 cm x 91.4 cm (5ft wide x 3ft high)
7-7-6	Roof openings	
	Silencer	
	Air inlet (if req'd)	
	Cooling piping	
	HVAC	

7-8 Plumbing

7-8-1	City water	L/min (...GPM)
7-8-2	Sour	
7-8-3	Fire protection	
	(sprinklers) per local legislation	
7-8-4	Shop air	
	Pressure	480 - 690 kPa (70-100PSI)

7-9- Electricity

7-9-1	AC feed for power	
	Amperage	(later)
7-9-2	AC & DC for controls & instrumentation	
7-9-3	Cable trays, power cables, control cables	

7-10 Acoustic

7-10-1 Noise level

7-10-1-1 Indoor

Engine room	90 DBA
Control room	70 DBA

7-10-1-2 Outdoor 60 DBA

7-11 Heating ventilation/air conditioning

7-11-1	Indoor temp.	21°C (70°F)
7-11-2	Air change	
	Engine room	6/HR
	Control room	3/HR
7-11-3	Filtration	Later

7-12 Miscellaneous

7-12-1 Service platform

7-12-2 Storage facilities

8- HANDLING

8-1 Jib Crane

Capacity	907 kg (2 tons)
Type	wall mounted or pillar or mast
Reach	3.66 cm (12ft)
Height (hook)	3.66 cm (12ft)

Note: To be capable to lift anything in the cell except the engine, (estimated 6000 kg) which can be brought in by mobile crane thru the 12ft high door or rolled in on a skid.

9- CONTROLS

9-1 Motor control centre

ITEM	IDENTIFICATION	FUNCTION	SIZE	VOLTAGE
1	Compressor	a) starting	(later)	
		b) charge air		
2	Fuel pump	a) booster		
		b) transfer		
3	Lube oil pump			
4	Water pump	a) to cooling tower		
		b) to dyno		
		c) to engine & A.C.		
5	Crankcase exhauster			

10- INSTRUMENTATION

10-1 Data sensors

ITEM	IDENTIFICATION	TEMPERATURE	PRESSURE	FLOW
1	Exhaust gas	x	x	x
2	Inlet air after heater	x		x
3	Charged air before cooler	x	x	
4	Charged air after cooler	x	x	
5	Jacket water inlet	x	x	x
6	Jacket water outlet	x	x	x
7	Cyl. head water inlet	x	x	x
8	Cyl. head water out	x	x	x
9	After cooler water in	x		x
10	After cooler water out	x		x
11	Fuel oil to engine	x	x	x
12	Fuel return		x	x
13	Fuel or drain		x	x
14	Lub oil at engine in	x	x	x
15	Lub oil at engine out	x		
16	Dyno water inlet	x	x	x
17	Dyno water outlet	x		
18	Water inlet to tower or rad	x	x	x
19	Water outlet from tower to rad	x		
20	Crankcase vacuum		x	
21	Cylinder pressure		x	
22	Injection pressure		x	
23	Blow-by			x

10-2 Data indicators

ITEM	IDENTIFICATION	
1	Speed sensor	
2	Hour meter	
3	Viscometer	a) fuel oil b) lube oil
4	Turbo speed	
5	Smoke meter	
6	Rack position	
7	Needle lift	
8	Shaft position indicator	
9	Engine torque	
10	Engine speed	
11	Motoring torque	
12	Expansion tank level	

10-3 Data acquisition

1) Visual display terminal
2) Recorder
3) Printer

10-4 Alarm Panel

ITEM	IDENTIFICATION	TEMPERATURE	PRESSURE	FLOW	LEVEL
1	Dyno inlet water	HIGH	LOW		
2	Dyno outlet water	HIGH			
3	Cooling water or rad freezing	LOW			
4	Jacket & cyl head water inlet		LOW	NONE	
5	Jacket & cyl head water outlet	HIGH			
6	Lub oil inlet		LOW		
7	Lub oil outlet	HIGH			
8	Fuel oil inlet		LOW		
9	Differential press. across L.O. Filter		HIGH		
10	Starting air		LOW		
11	Expansion tank				
12	Cold well				LOW
13	Overspeed				LOW
14	Fire				LOW

APPENDIX "C"

TO

REPORT 484100

DESIGN OF A SINGLE CYLINDER
MEDIUM SPEED RESEARCH ENGINE
AND TEST FACILITY

FIG. I TEST CELL LAYOUT

FIG. II SCHEMATIC DIAGRAM - COOLING WATER

FIG. III SCHEMATIC DIAGRAM - COMBUSTION AIR

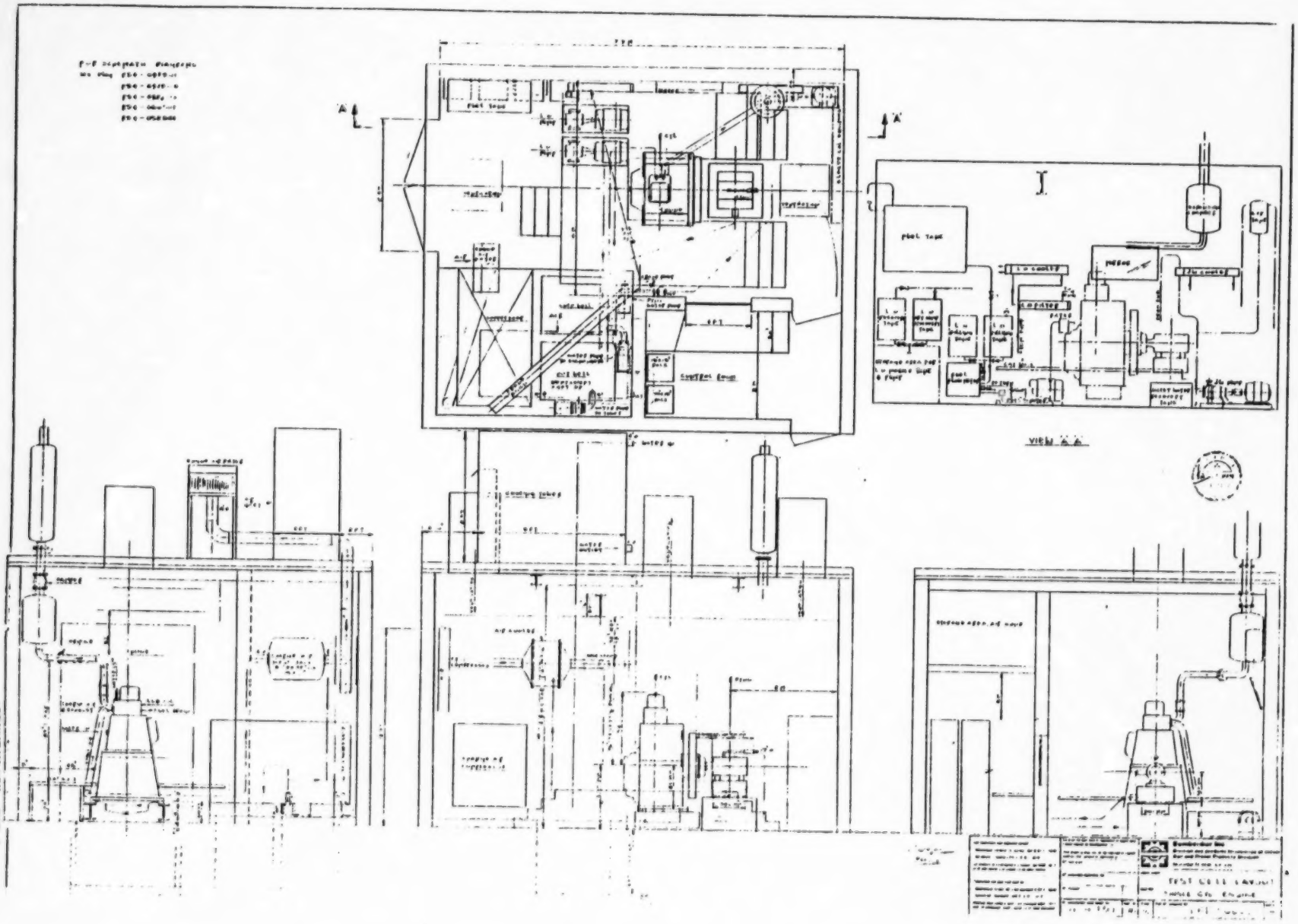
FIG. IV SCHEMATIC DIAGRAM - LUBE OIL

FIG. V SCHEMATIC DIAGRAM - FUEL OIL

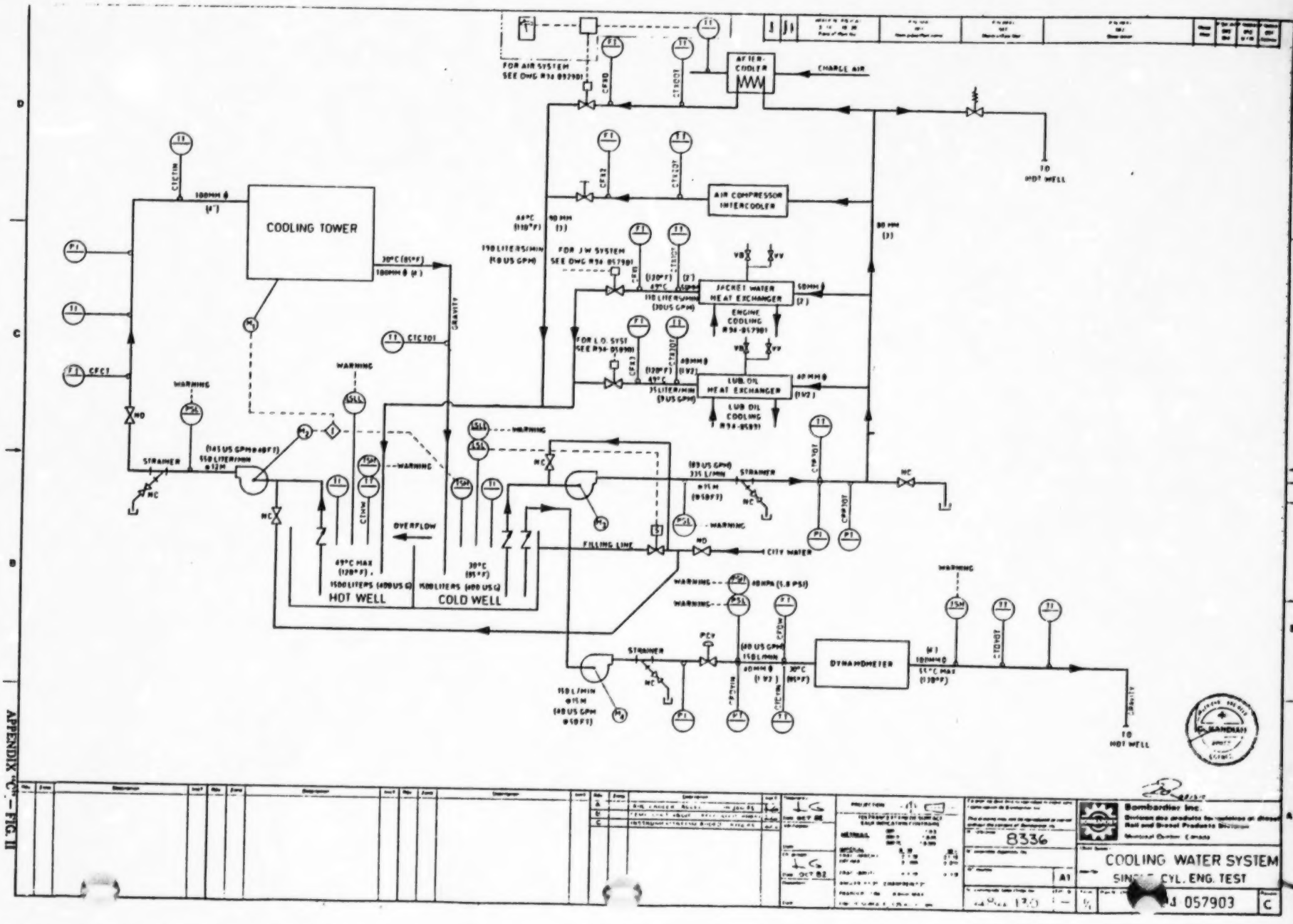
FIG. VI SCHEMATIC DIAGRAM - ENGINE COOLING

FIG. VII SCHEMATIC DIAGRAM - DATA ACQUISITION

GLOSSARY OF SYMBOLS

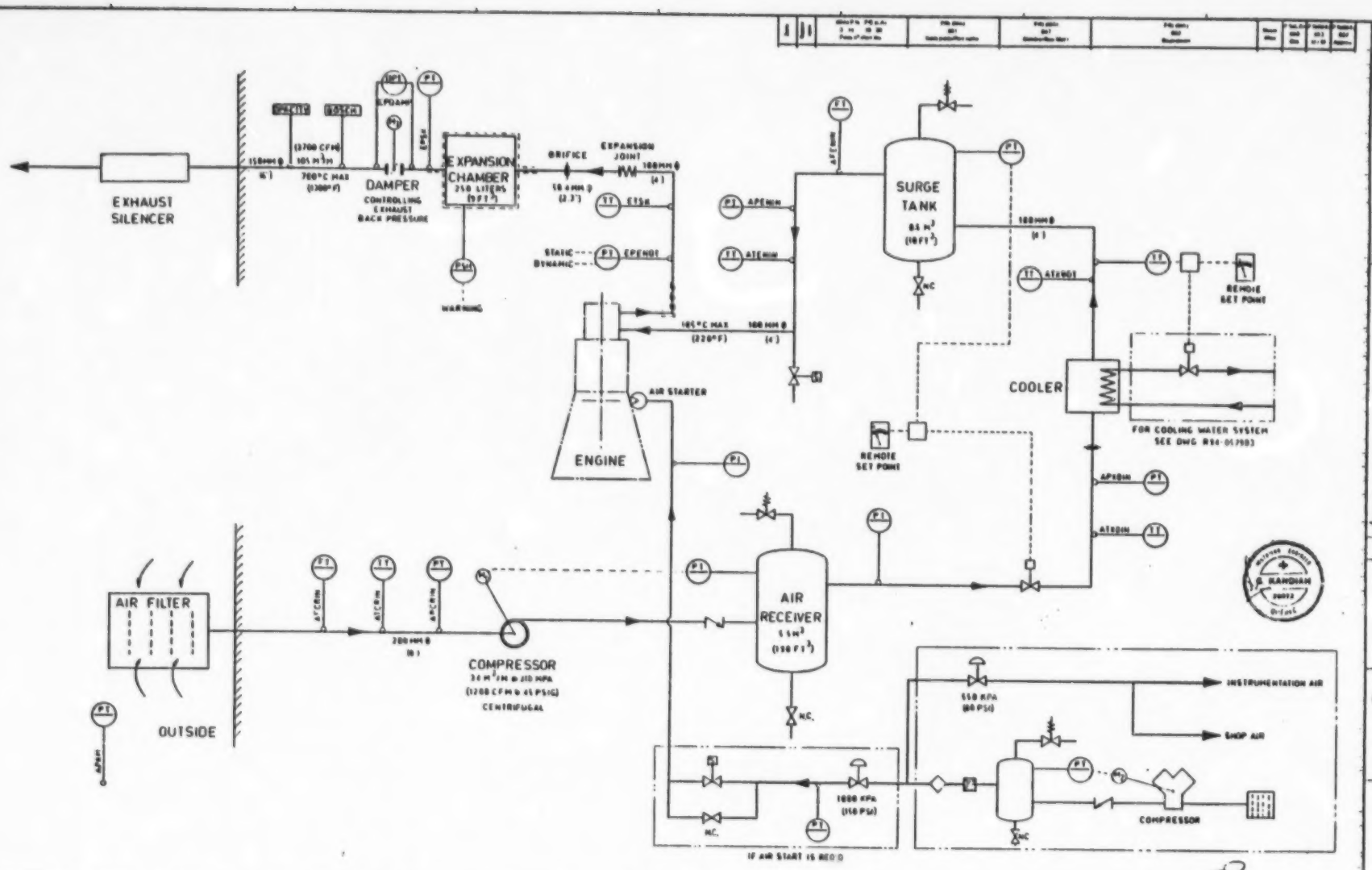


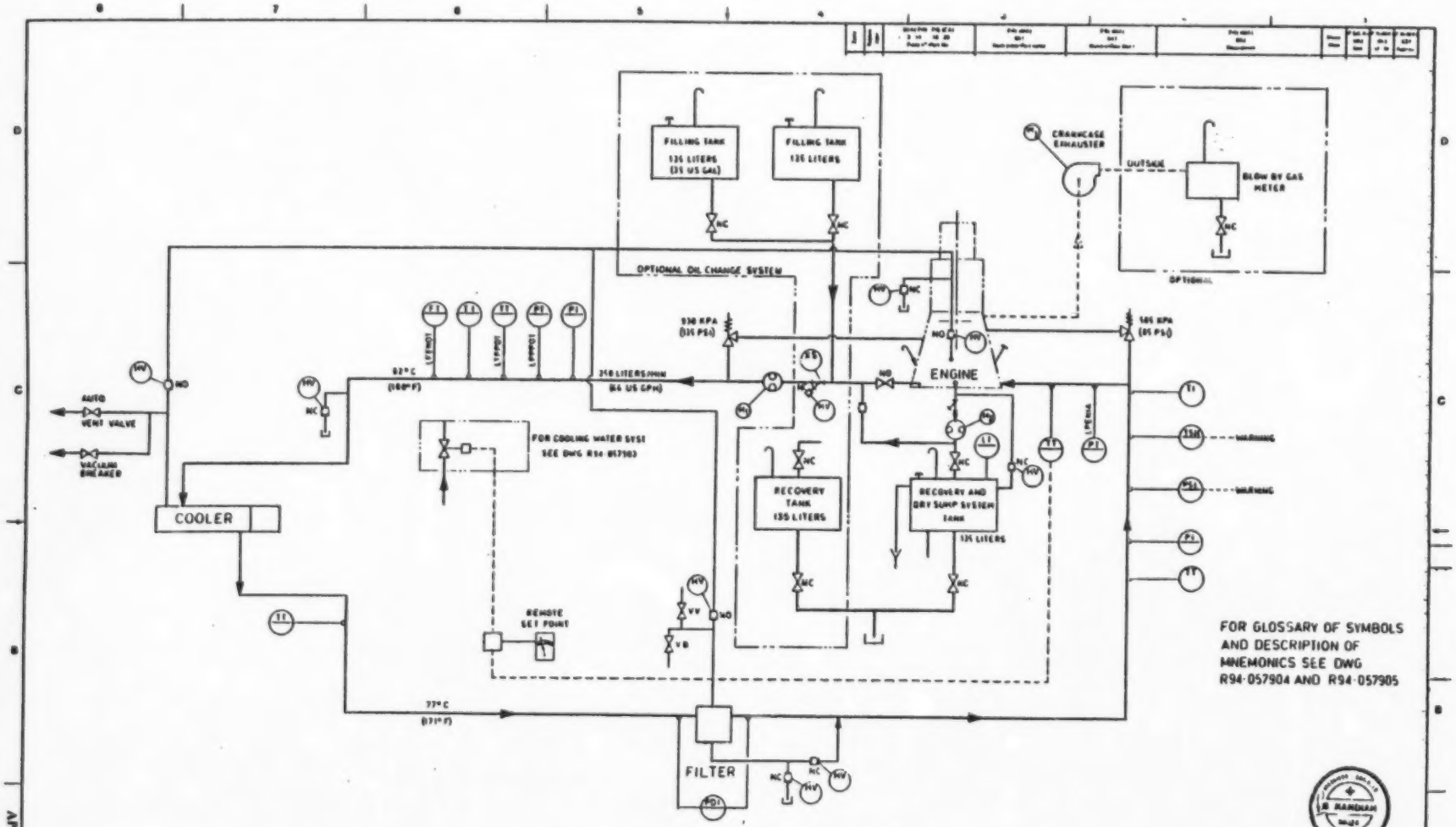
APPENDIX "C" – FIG. 1



APPENDIX "C" – FIG. II

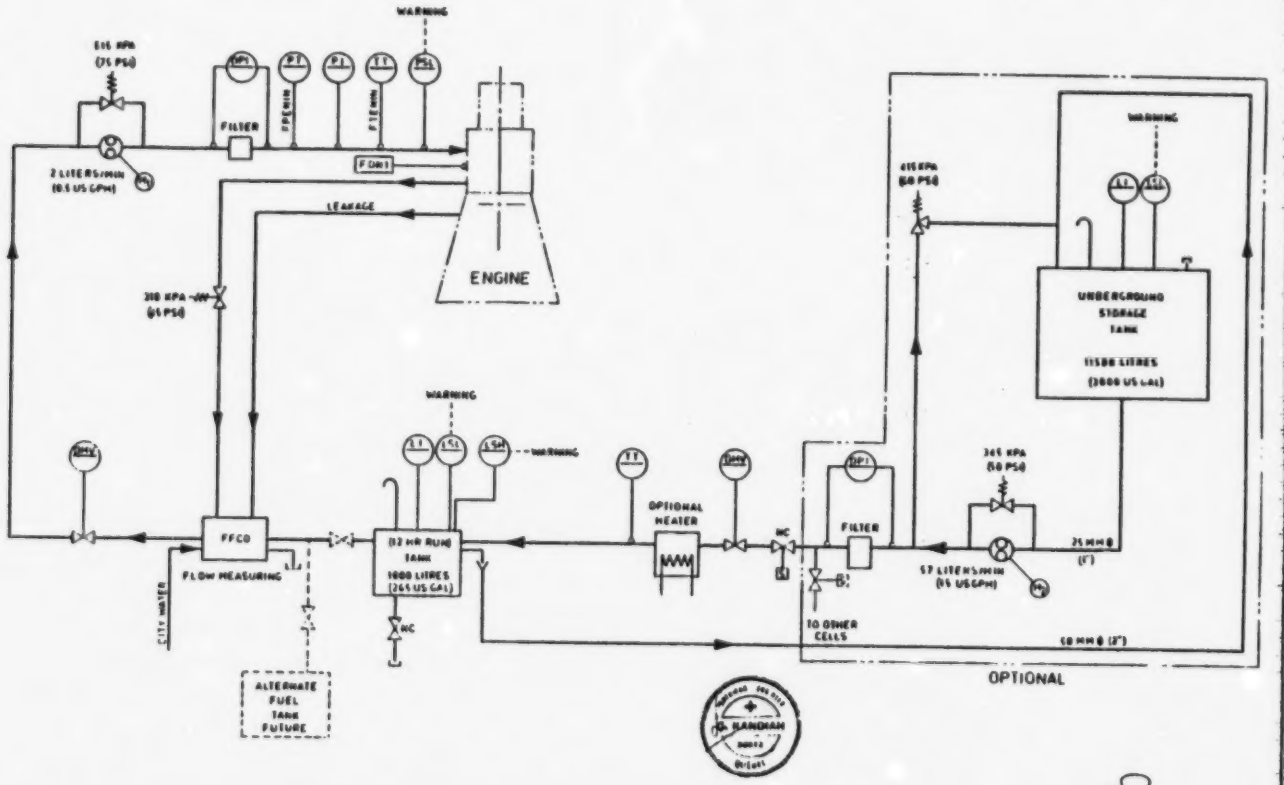
Bombardier Inc.	Division des produits ferroviaires et diesel Rail and Diesel Products Division
8336	COOLING WATER SYSTEM SINGLE CYL. ENG. TEST
A1	057903 C


EXHAUST SILENCER
DAMPER
CONTROLLING EXHAUST BACK PRESSURE
EXPANSION CHAMBER
250 LITERS
ORIFICE
EXPANSION JOINT
SURGE TANK
ENGINE
AIR STARTER
COOLER
REMOTE SET POINT
FOR COOLING WATER SYSTEM SEE DWG R94-051703
AIR FILTER
OUTSIDE
COMPRESSOR
CENTRIFUGAL
AIR RECEIVER
550 KPA (80 PSI)
INSTRUMENTATION AIR
SHOP AIR
1000 KPA (150 PSI)
IF AIR START IS REQ'D
Bombardier Inc.
AIR SYSTEM
SINGLE CYL. ENG R4D
8339
484 130
R94-092901



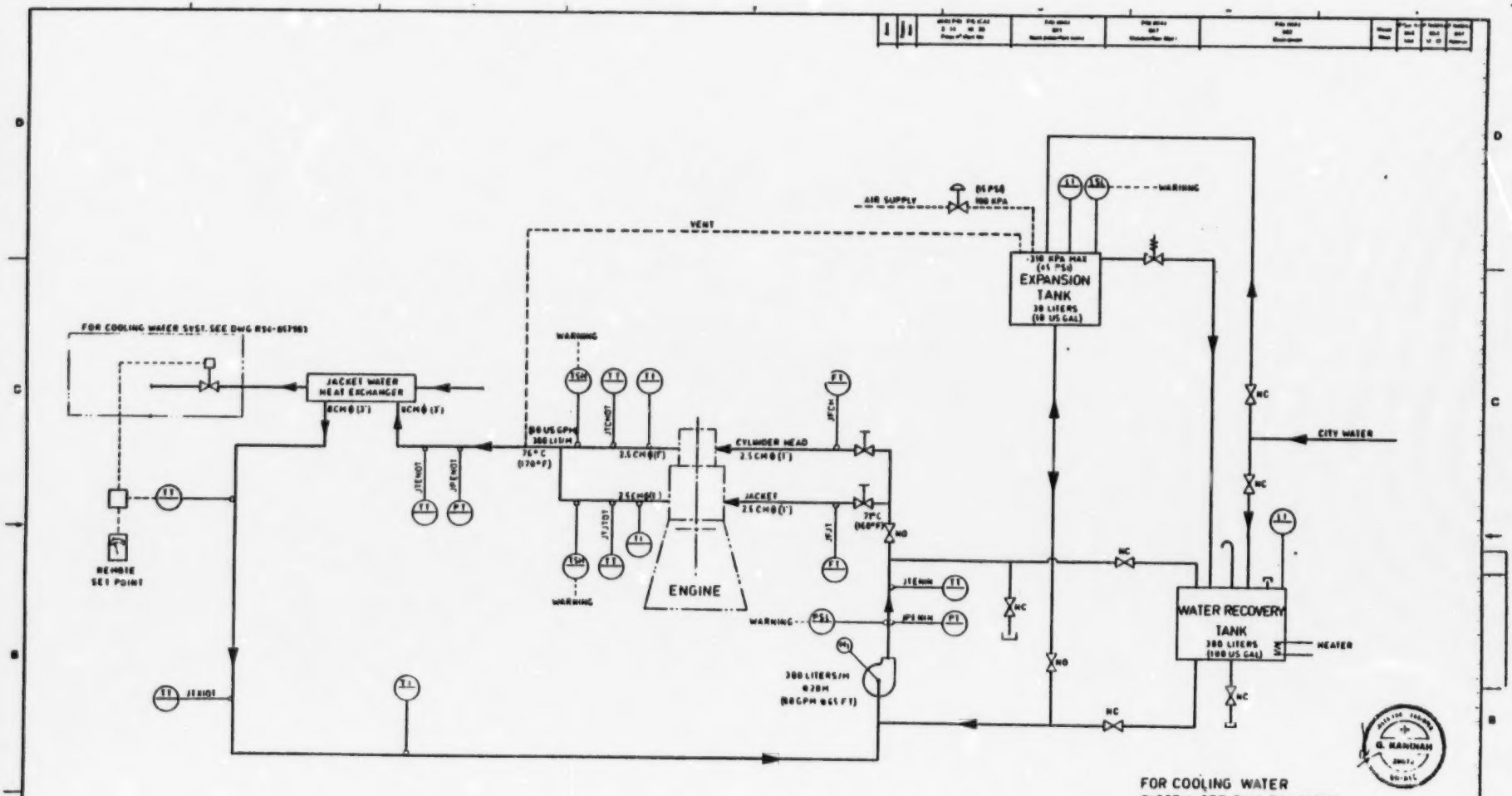
APPENDIX "C" – PAGE IV

Bombardier Inc. Division des produits ferroviaires et divers Rail and Diesel Products Division Montreal Quebec Canada			
	8337		LUB. OIL SYSTEM SINGLE CYL. ENG. TEST
	A1		
484 130	–	1	R94-058901 A



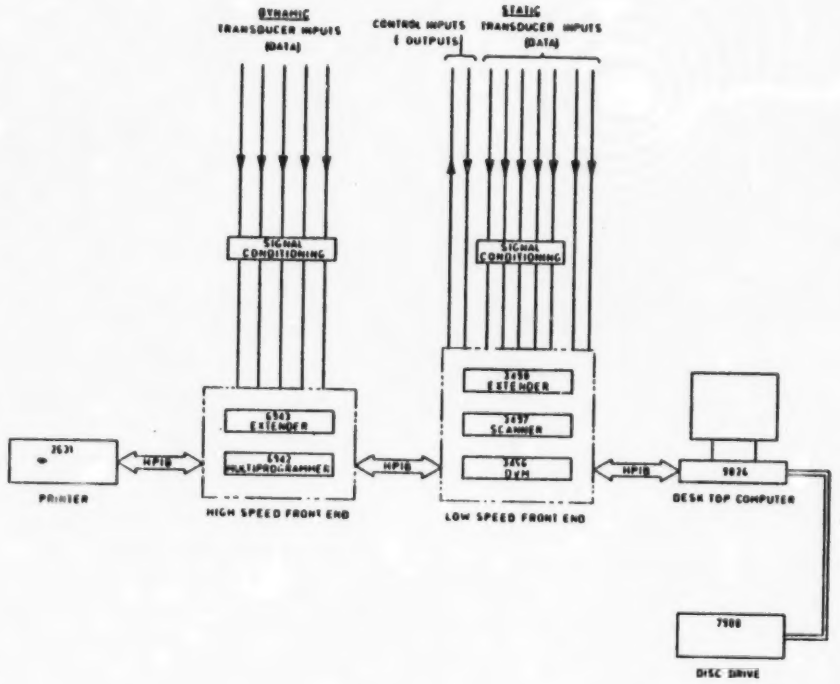
APPENDIX "C" – FIG. V

| | | |



Bombardier Inc.	8338			ENGINE COOLING SYSTEM	
		A1		SINGLE CYL ENG TEST	
	484 130	—	1/1	R94-057901	B

APPENDIX "C" – FIG. VI

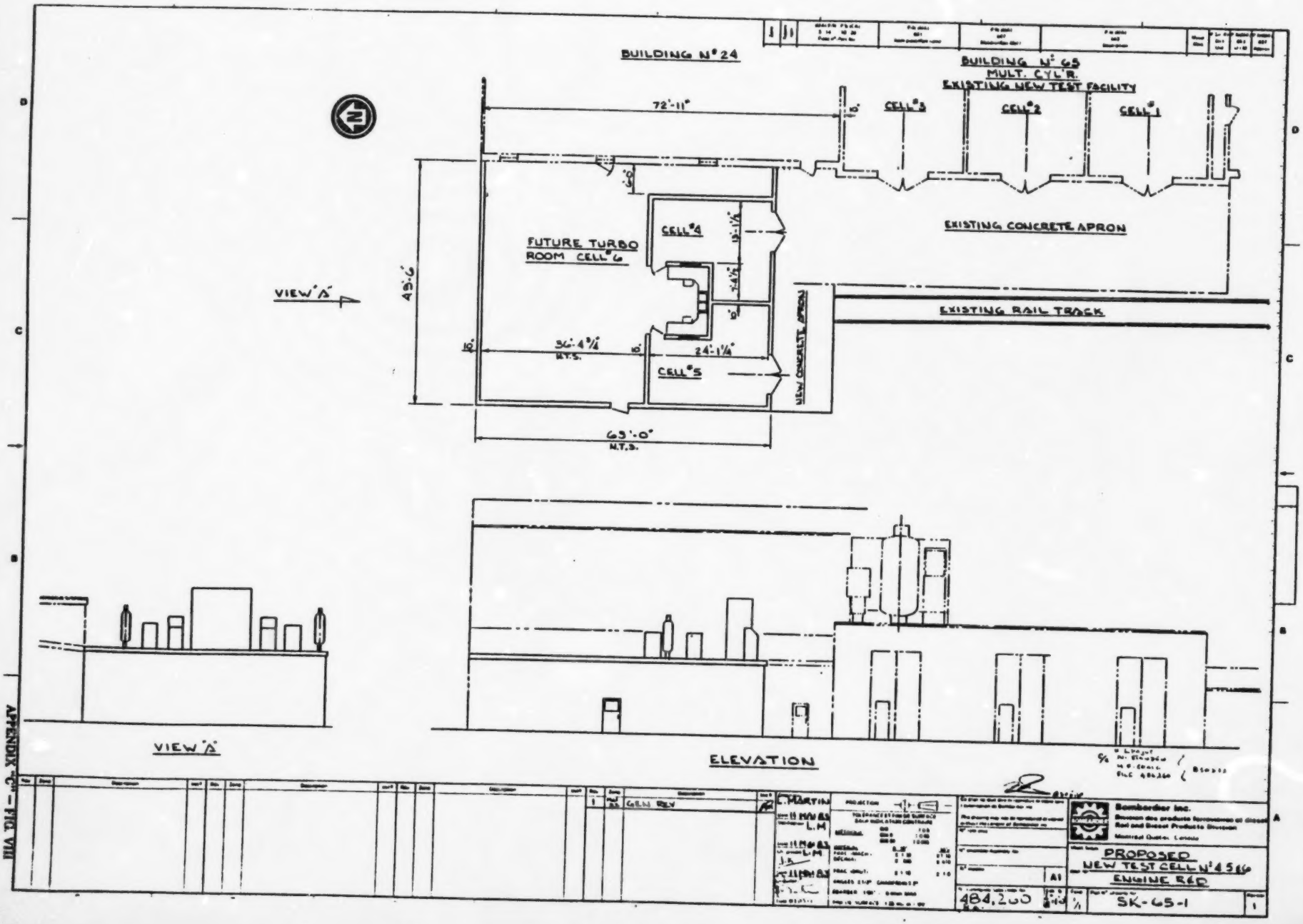


APPENDIX "C" – FIG. VII

Bombardier Inc.
Division des produits ferroviaires et divers
Rail and Diesel Products Division
Montreal Quebec Canada

COMPUTERIZED DATA ACQUISITION & CONTROL SYSTEM
SINGLE CYL ENG TEST CELL

484 136 | A1 | — | 1/1 | R94-050902 | —


BUILDING N° 24
BUILDING N° 65
MULT. CYL'R.
EXISTING NEW TEST FACILITY
72'-11"
CELL°3
CELL°2
CELL°1
CELL°4
FUTURE TURBO
ROOM CELL°6
EXISTING CONCRETE APRON
EXISTING RAIL TRACK
VIEW 'A'
45'-6"
36'-4 7/8"
N.T.S.
24'-1 1/4"
CELL°5
NEW CONCRETE APRON
65'-0"
N.T.S.
VIEW 'A'
ELEVATION
APPENDIX "C" - FILE VIII
GEN REV
C. MARTIN
L.M
Bombardier Inc.
Division des produits ferroviaires et diesels
Rail and Diesel Products Division
Montreal Quebec Canada
PROPOSED
NEW TEST CELL N°4 & 5
ENGINE R&D
484,265
SK-65-1

APPENDIX C

24 January 1983.

Activity No. 484 134

GLOSSARY OF SYMBOLS

FOR SCHEMATIC DIAGRAMS